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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Sandaire reports SAE 77-005 and SAE 78-016, prepared under contracts N62269-77-C-0046 and N62269-78-Q-5137, contain descriptions of a preferred rigid skirt hold-down system concept and a one-half scale laboratory model based on the rigid skirt concept. This report is a proposed test plan to obtain the data needed to project and evaluate the performance of a full scale system. Key issues of the planned testing include: air bearing seal leakage rates; loss of hold-down force while traversing flight deck

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20. Obstacles (tie-down fittings, door seals, etc.) and the magnitude of towing drag forces encountered during traversing. In addition to the test plan, data requirements and test equipment/apparatus requirements are addressed.

SANDAIRE

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TEST PLAN

FOR A ONE-HALF SCALE
LABORATORY MODEL OF A
RIGID SKIRT HOLD-DOWN SYSTEM

SAE 78-027

September 29, 1978

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Submitted to

Commander, Naval Air Development Center
Warminster, Pennsylvania 18974

PREFACE

This report is submitted under Contract No. N62269-78-M-8646 and presents the Test Plan, requested by Task 1 of the contract, for the one-half scale laboratory model built in response to Purchase Request No. 62269/SR7-5050. The model is described in Report No. SAE 78-016 dated May 1, 1978 and simulates the features of the Rigid Skirt Hold-Down System concept developed under Contract No. N62269-77-C-0046 and presented in Report No. SAE 77-005 dated March 21, 1977.

Task 2 of the referenced contract, scheduled to be submitted on or before November 4, 1978, consists of the design and construction of a carriage-like structure representing a pseudo airframe to support the model, and a suitable trailer carriage to support the Rotron DR8 blower, powered by a 10 HP electric motor, purchased for the test and delivered to Sandaire April 12, 1978. This blower will be used in the test to provide the suction for the model. The suction would be supplied by aircraft systems in an actual application.

In addition, a simulated flight deck surface at least 21 feet long and 7 feet wide is needed for the test, with one-half scale deck obstacles such as roughness, hangar door sills and tracks, and deck tie-down fittings that could cause loss of suction, and therefore decrease of hold-down force, during simulated deck traversing tests.

Sandaire is prepared to quote on conducting the planned test and demonstration program for the model to obtain data for further evaluation of this Hold-Down concept for V/STOL aircraft that operate off landing pads on small aircraft capable ships.

SANDAIRE

TABLE OF CONTENTS

I.   TEST OBJECTIVE

To review briefly, the Rigid Skirt Hold-Down System consists of an essentially oval, horizontal platform attached to an aircraft. Air cylinders connect a rigid skirt to the platform so that a seal between the platform and the landing deck can be maintained. Suction is provided between the platform and the deck that produces a hold-down force. This is shown schematically on Page 6.

The basic goal for the Hold-Down System, when operational on full-scale aircraft, is to provide additional load on the aircraft tires, without any side force. Therefore, greater braking can be obtained to prevent the aircraft from sliding on a sloping, wet deck, without appreciably increasing the towing force with brakes off. This will be achieved if the average airfilm between the seal and the deck, due to leakage under the seal, reduces the average seal sliding friction to a low value. Then the only significant increase in towing force will be the added rolling friction due to the additional hold-down load on the aircraft tires.

The basic test objective is to obtain model test data that will be applicable to full-scale aircraft, that use the Rigid Skirt Hold-Down System, for which the suction hold-down force and the towing force for deck traversing can be predicted for various deck conditions. Of particular interest is the loss in suction force for deck traversing of obstacles such as deck roughness, hangar door sills and tracks, and deck tie-down fittings, including the effectiveness of the model cylinder technique (that collapses the seal against the deck) in preventing or decreasing this suction loss. In addition, the effectiveness of the particular seal, used on the model (Rubbercraft No. 1606; see Page 2), will be evaluated. It is anticipated that alternative seals will be tried. For example:

(a) Seals with various size voids (greater or smaller wall thickness).

(b) Seals with void filled with a sponge rubber of sufficient density to reduce seal collapse about 50% when under cylinder load.

(c) Some combination of (a) and (b) with a bottom wear strip (possibly laterally grooved) on the thinner wall thicknesses.

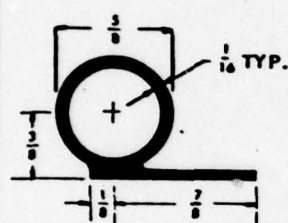(d) Multiple or single-leaf type seals (possibly segmented).

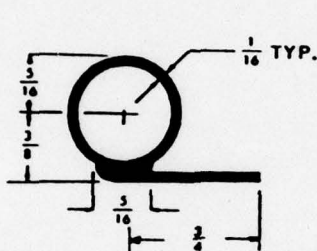Selection of alternative seals probably should await some tests of the present seal.
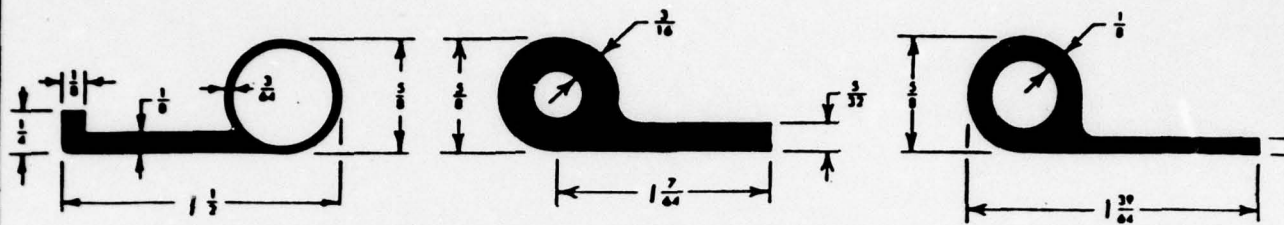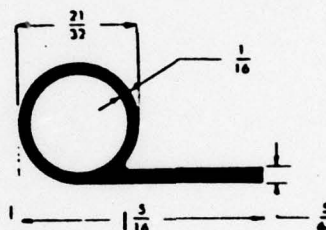
834

1339

1106

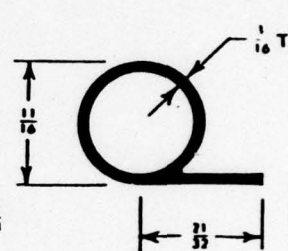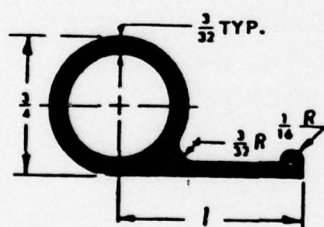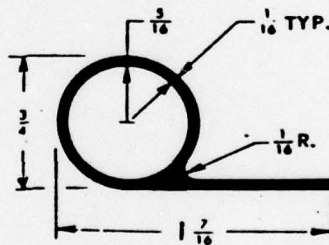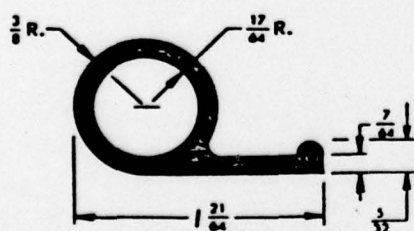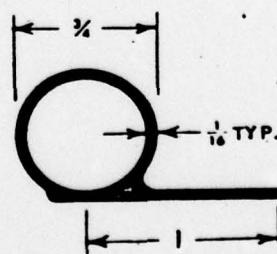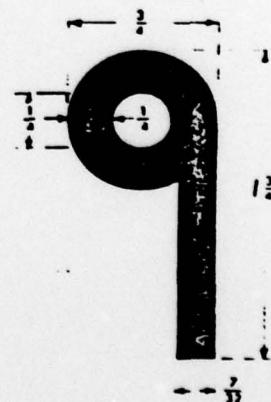1031

1950

1589

1251

1606

1173

427X

1097

1298

II. MODEL

The model is described in Report No. SAE 78-016 dated May 1, 1978. It is called a one-half scale model because the base point conceptual design, developed in Report No. SAE 77-005, provided for a design suction force of 10,000 pounds. The model is designed to a suction force of 5,000 pounds.

The model will be supported on a carriage that represents the attachment to an airframe. A simulated flight deck surface, at least 21 feet long by 7 feet wide, will be used with one-half scale obstacles such as deck roughness, hangar door sills and tracks, and deck tie-down fittings.

From the model drawing 77-523 (Figures 4 and 5, Report No. SAE 78-016), the 3/4-inch O.D. Rubbercraft No. 1606 neoprene seal (between the model platform and the simulated deck) has the following dimensions to centerline of seal.
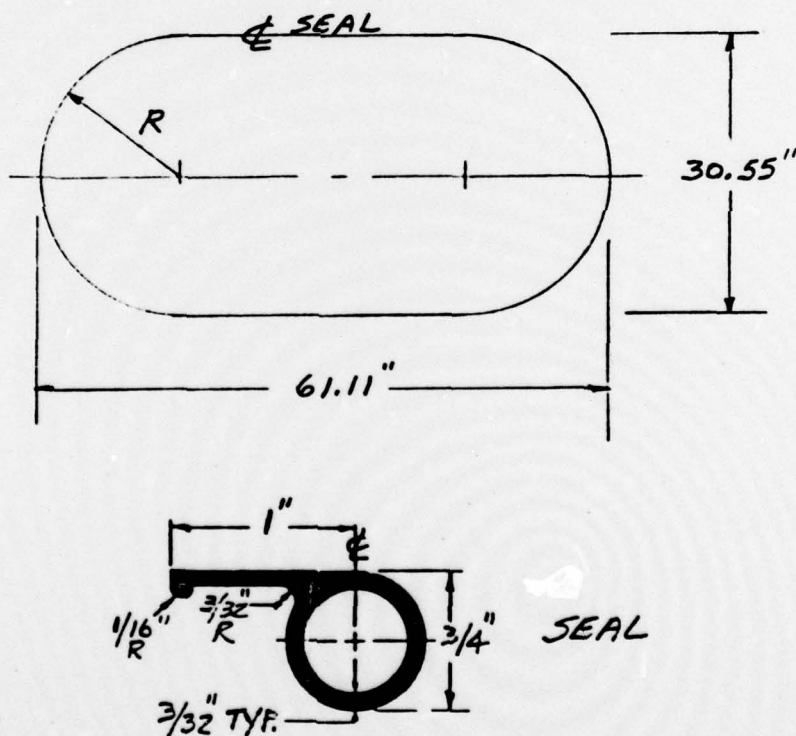
Area inside seal centerline (A) which is the hold-down area

$$= [\frac{30.55^2 \pi}{4} + 30.55 \, (61.11 - 30.55)] \, / 144$$

$$= 11.57 \text{ square feet}$$

Seal centerline length (C)

$$= 30.55 \pi + (61.11 - 30.55) \times 2$$
$$= 157.10 \text{ ins.} = 13.091 \text{ ft.}$$

The model design suction, as agreed with NADC personnel, is 3 psi. The suction force (F) at 3 psi

$$= 3 \times 144A = 5000 \text{ pounds}$$

A stress analysis of the model was done in Report No. SAE 78-016 dated May 1, 1978.

The blower that was purchased for the test and delivered to Sandaire on April 12, 1978 provides the suction force for the model and is Rotron DR8 with a 10 h.p. electric motor. An actual application of the hold-down system would use aircraft systems to provide the suction. The blower will be mounted on a suitable trailer carriage pulled by the carriage that supports the model. A side benefit of this arrangement will be the isolation of the model from compressor vibration, if any. The blower manufacturer's preliminary specification data gives rated blower performance as plotted on Page 5. For the 3 psi design suction, airflow (Q) is 175 cfm.

The seal leakage velocity (V) between the seal and the simulated flight deck for 3 psi suction, sea level, standard, is approximated by (this assumes no leakage at the flat seal between the model platform and the rigid skirt):

$$1/2 \, \rho \, V^2 = 3 \times 144$$

where ρ = air density/g = .075/32.2

V = approximately 600 ft/sec for incompressible flow

The effective leakage gap (h) between the seal and the deck is calculated from

$$Q = KAV; \quad A = hC$$

where K = discharge coefficient
       h = effective seal leakage gap

$$h = [(175/60) \times (12/13.091)] / VK$$

where h is in inches
       V is in ft/sec

$$h = .004 \text{ to } .009 \text{ inches for discharge coefficients } 1.0 \text{ to } 0.5$$

The above values may not be completely correct; however, they do show the order of magnitude of the seal leakage gap.

SANDAIRE

ROTRON DRB
REGENERATIVE BLOWER
STD AIR - SEA LEVEL

SUCTION

HP

STATIC PRESS. - PSIG

10
8
6
4
2
0

6
5
4
3
2
1
0

AIRFLOW - CFM

40   80   120   160   200   240   280   320   360

21.0

20.0
DIA.

8.50
11.0
25.0

2½" NPSC THD TYP.

CONNECTOR
HOLE

.593 DIA.
(4 HOLES)

8.50
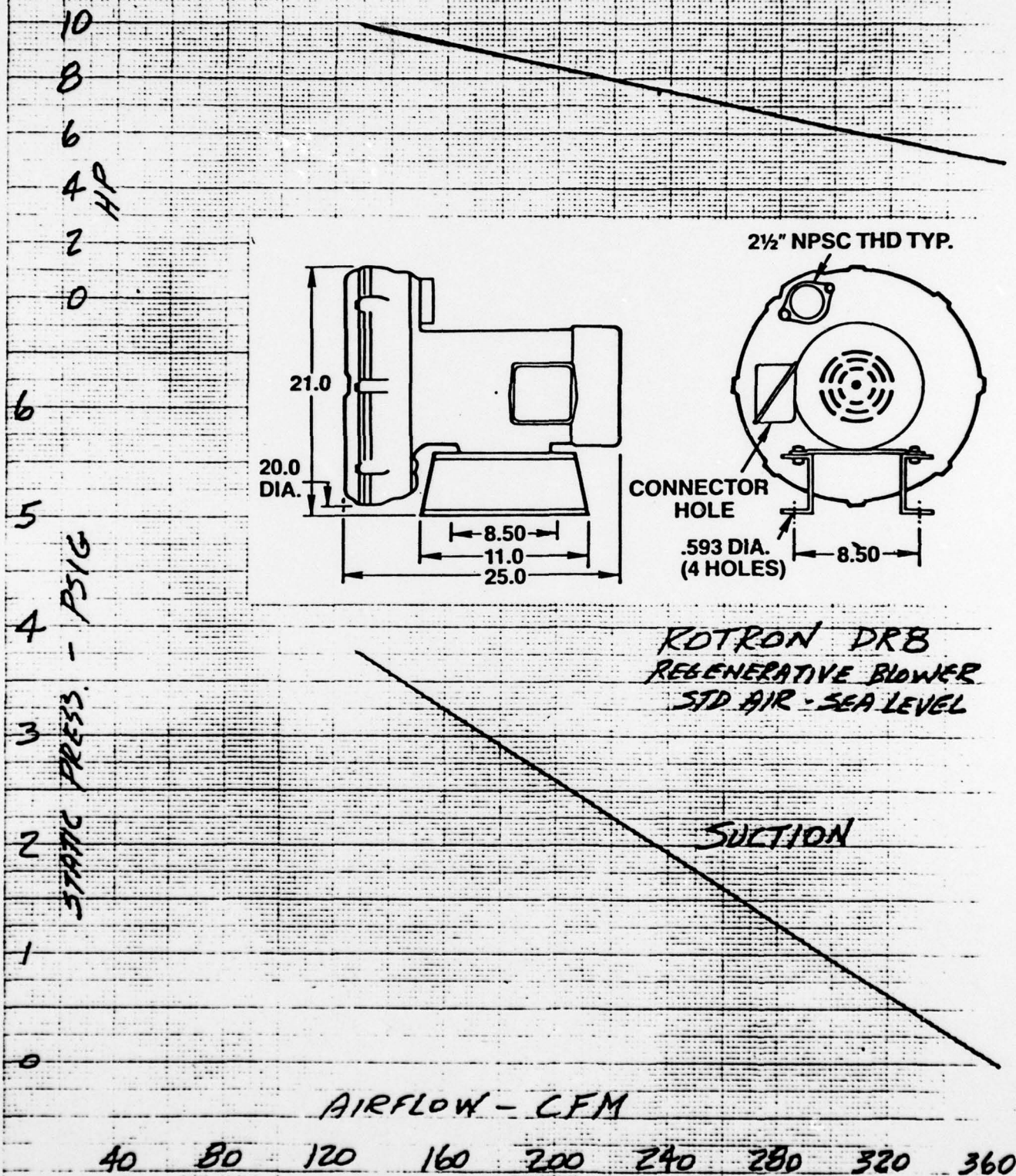
The seal is held off the deck by two spring-loaded Bimba 1 3/4-inch bore by 2-inch stroke air cylinders, No. 240NR, as shown schematically below. Compressed air to the cylinders will lower the seal and collapse the seal against the deck. The spring force per cylinder vs stroke, from the manufacturer's data, is 11 pounds to 24 pounds for the 2-inch stroke. The weight of the model skirt, seal and actuators assembly is 36 pounds; therefore, the springs will be approximately one-half compressed with the cylinder air off. Piston area is $(1.75^2 - 0.5^2) \frac{\pi}{4} = 2.209$

square inches each, and the force exerted by the cylinders on the skirt assembly is (2.209) x (2 cylinders) x (psi applied to the cylinders) - (resisting force of the collapsed springs). The cylinder psi required to collapse the spring, with the seal off the deck, is

$$[(24) - (36/2)]/2.209 = 2.7 \text{ psi}$$
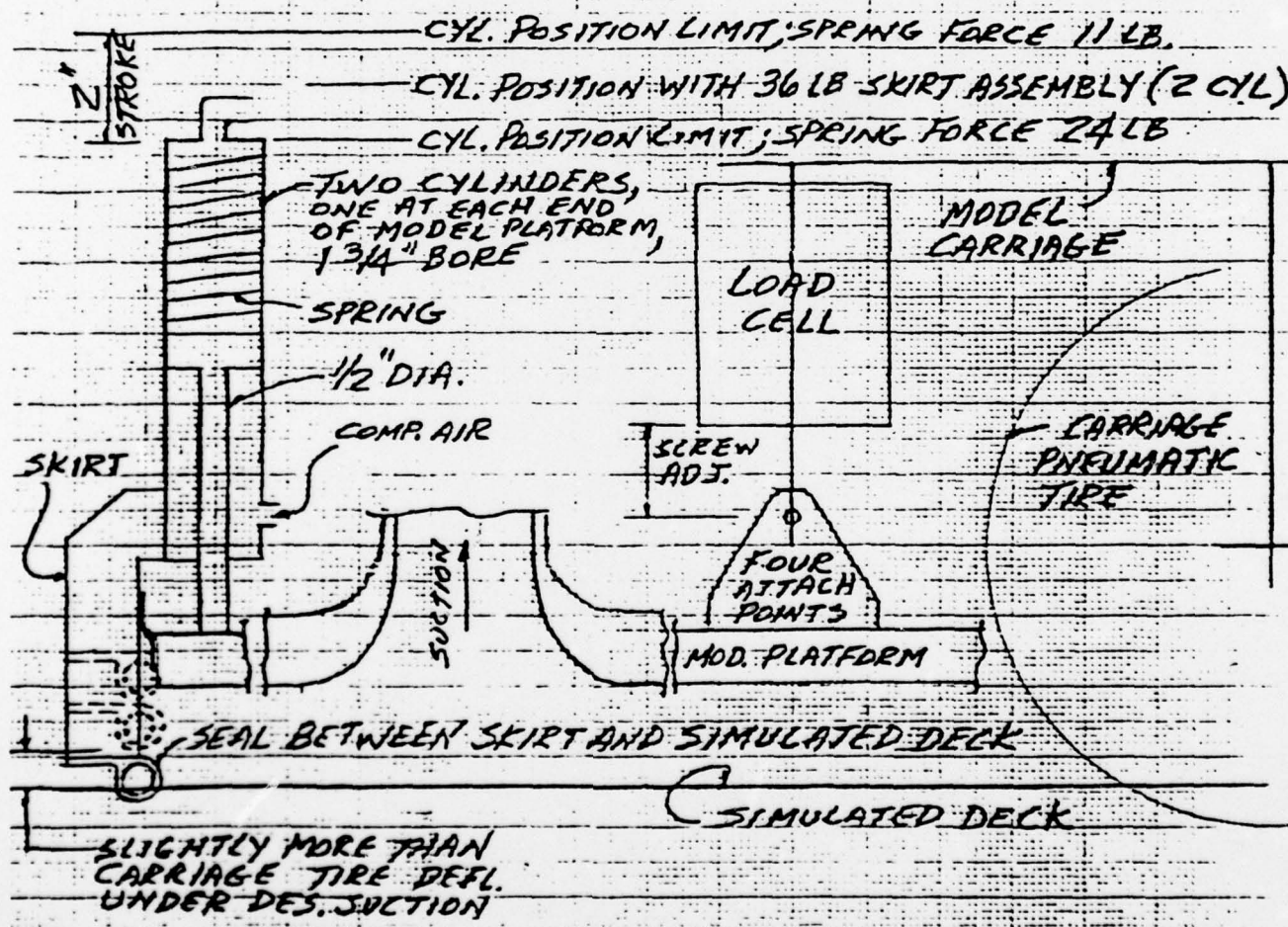
Application of the design 3 psi suction to the model platform will compress the pneumatic tires on the model carriage. The tire manufacturer's drawing (Aerol No. 12112) shows 0.62 inches compression at the rated load of 1200 pounds/tire at 5 mph. The estimated weight of the model carriage and model is 320 pounds, which gives a load for each of the four tires of about 1330 pounds with 3 psi design suction. This is considered satisfactory for use in the test.

The seal-to-deck clearance, with cylinder air off, will be adjustable by screws on the model carriage. This clearance will be set initially at slightly more than the carriage tire deflection with maximum suction. The remaining approximately one inch cylinder stroke from the static condition should be adequate to compress the seal against the deck and obtain design suction.

In order to compress the seal further and attempt to hold design suction when deck obstacles are traversed, that cause loss of some or all suction, fairly high pressure to the cylinders may be required. Static compression tests of an 8-inch length of seal showed 21.3 pounds/inch load required to collapse the seal 0.53 inch, decreasing linearly to 5.6 pounds/inch with the seal collapsed 0.34 inch (approximately 65%), and then linearly to zero with no seal collapse. For the cylinder rating of 250 psi, the load on the 13.091 foot seal is

$$\frac{(250) \times (2\ cyl) \times (2.209)}{13.091 \times 12} = 7\ pounds/inch$$

which will collapse the seal

$$\frac{7-5.6}{21.3-5.6} \times (100-65) + 65 = 68\%$$

For simulated deck traversing tests, a simple steel cable and hand-operated winch should be satisfactory. With the rated 250 psi to the cylinders, full suction, and a mechanical advantage of 20

winch crank force (pounds) = (test rig rolling friction plus model sliding friction) /20

= [(5000 pounds suction + 800 pounds approx. test rig weight) x (.03) + (250 x 2.209 x 2) x μ] /20

= 9 + 55μ

Crank forces up to about 50 pounds should be acceptable for which μ is about 0.75. This is much greater than should be obtained if the model seal rides on the airfilm due to seal leakage, as anticipated. For deck traversing over an open depressed track channel, complete loss of suction may be obtained, depending on the size of the channel, and a removable channel filler may be needed.

III. TEST HARDWARE

A. AIRFLOW

The air connection between the compressors and the model is a nominal 2.5 inches in diameter. J-TEC ASSOCIATES, INC., 317 7th Avenue, S.E., Cedar Rapids, Iowa 52401 have a Model VF-570P air flowmeter with 2.5-inch nominal pipe size connections that should be satisfactory. It will require sections of straight pipe about 24 inches upstream and 12 inches downstream from the 2-inch instrumented section, as shown schematically below.
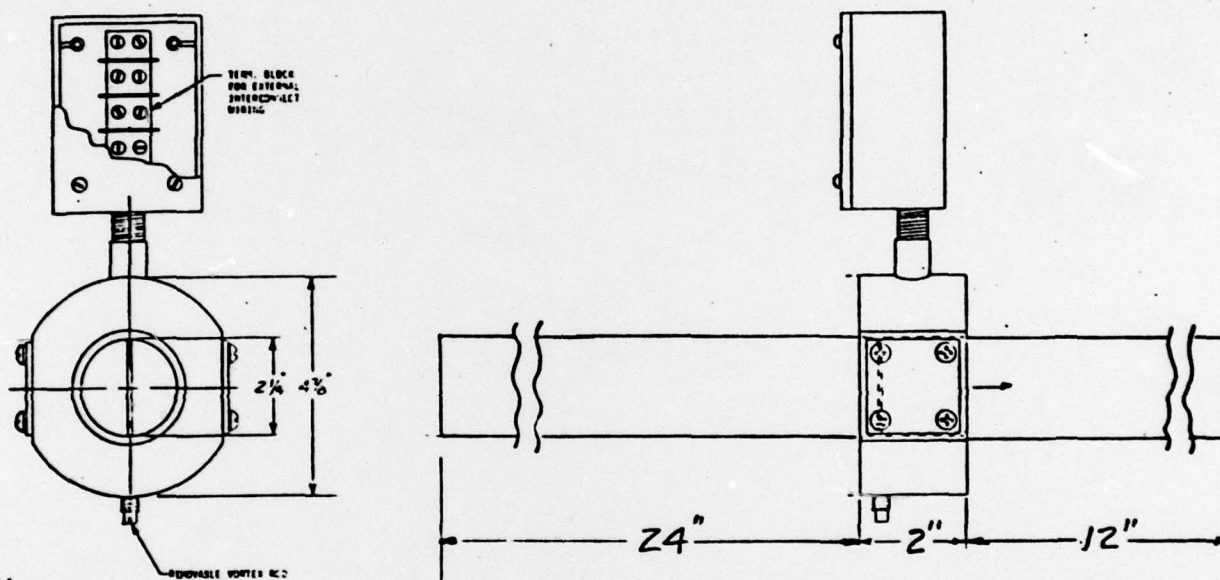
A J-TEC processor and direct readout meter is available and is pictured below.
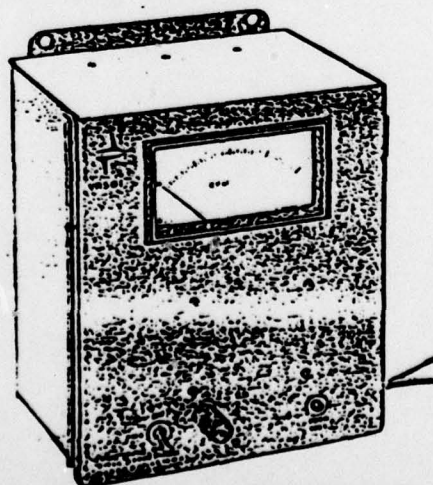
Cost of the flowmeter and the processor-meter is subject to quote.

A pressure relief valve must be installed in the suction pipe, downstream from the 12-inch section, to prevent exceeding the 3 psi design suction. In addition, an adjustable bleed-in valve is needed further downstream to allow tests at 3 psi suction with less than the 175 cfm rated airflow to the model. No suitable stock valves have been located to date. The search is continuing; if none are located in time to support the test schedule, improvised valves may be necessary.

B.   POWER SUPPLY

The required power supply for the compressor motor is 220/440 volt, 3-phase, 60-cycle, 10-kva capacity. It is assumed that a suitable portable generator package, with necessary equipment, cables, etc., can be rented for the test.

C.   LOADS, PRESSURES AND TEMPERATURES

(1) Load cells, installed at the four attachments of the model platform to the model carriage (see Page 6) will give the suction force between the model platform and the simulated flight deck. If the seal is in contact with the deck at any place, some feedback of the cylinder air pressure and spring force will be obtained at the load cells; however, no attempt will be made to measure it. The feedback may be calculated from the cylinder air pressure and the cylinder position. The BLH T3P1 (Baldwin-Lima-Hamilton, Waltham, Massachusetts) 2,000-pound load cell is shown below and should be satisfactory for the test. The BLH company has the necessary load totalizer and readout instruments, if not available at the test site. Prices are subject to quote.
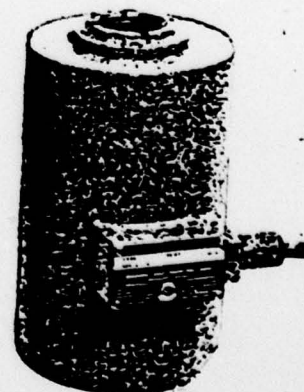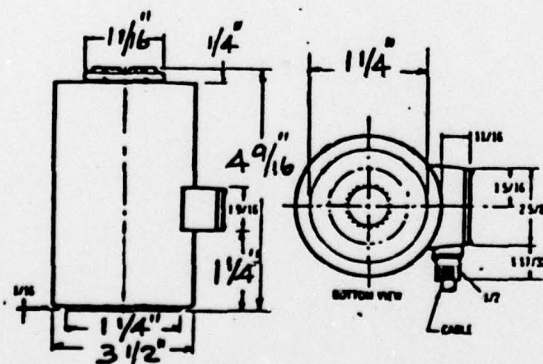
(2) It is assumed that normal laboratory pressure and temperature gages will be available at the test site to record ambient conditions and values at various locations as shown schematically below. The cylinder air pressure limit is 250 psi.
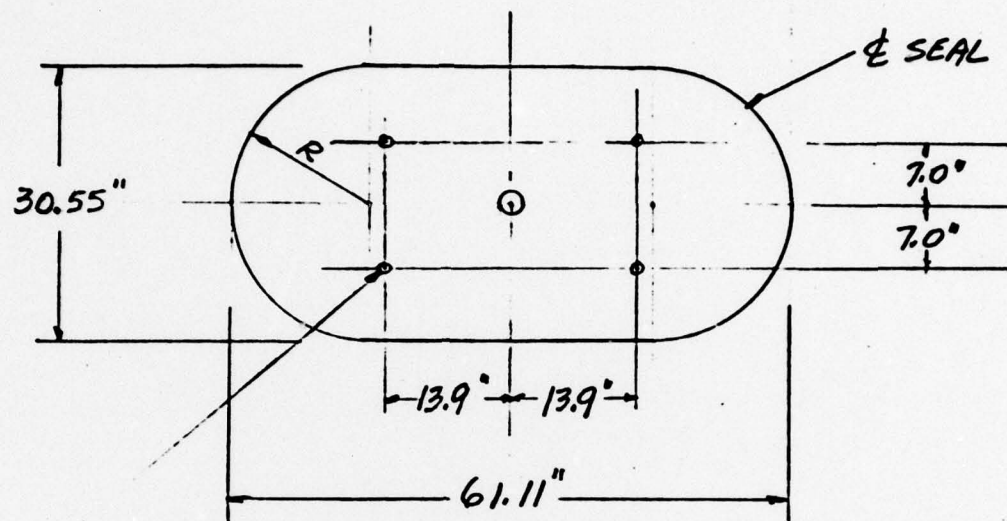
TEMP. AND SUCTION PRESS. (T & P) 4 PLACES BELOW MOD. PLATFORM AT CENTROID OF 1/4 AREA.
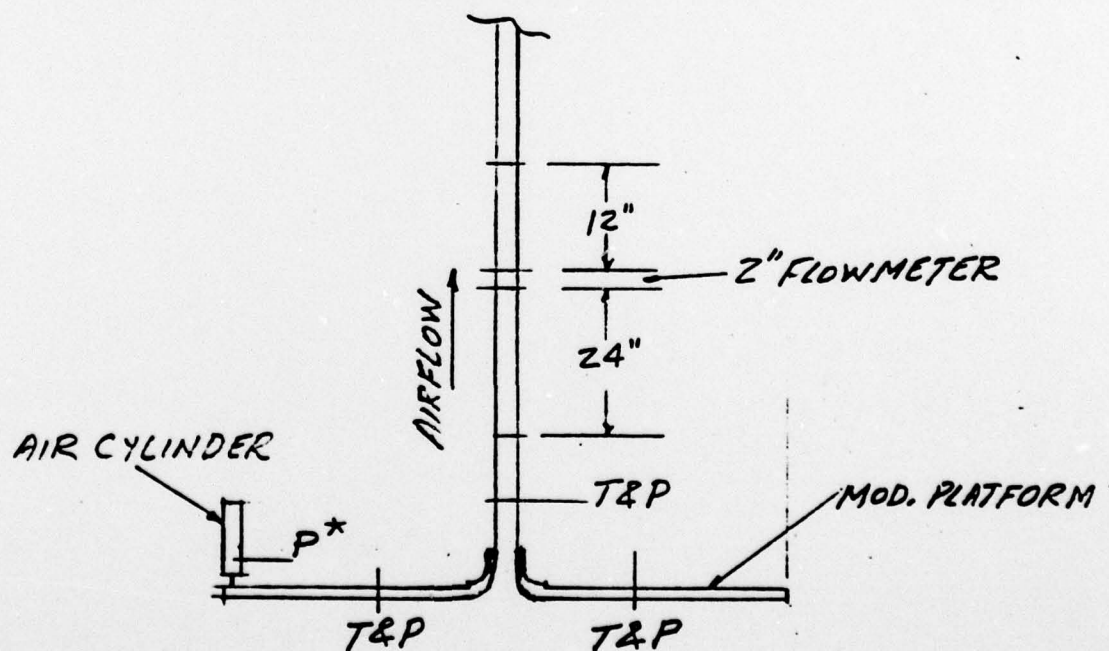
*MANIFOLDED TO THE TWO CYLINDERS

The suction pressure gage should have a range of zero to minus 5 psi. The two air cylinders will be manifolded to one gage. Preliminary check of the pressure below the model platform at each of the four locations may show that manifolding the four points with one gage will be satisfactory. Temperature gages should cover a range of at least 0°C to +40°C.

(3) The tension in the steel cable that pulls the model carriage will be no more than 1200 pounds and usually much less. A rented, calibrated spring scale should be satisfactory.

D. DIMENSIONS

Model platform to deck, bottom of skirt to deck (for seal collapse), cylinder stroke, and centerline of model carriage axle to deck (for tire compression), all can be measured by hand with standard scales with adequate accuracy. Obviously, these measurements will be taken at several points as the case may be.

E. OTHER HARDWARE

In addition to the above, other items are indicated in the above description of the model and the following description of the test plan. For example, compressor to model air piping, simulated flight deck with one-half scale obstacles, model and compressor carriages, winch, towing cable, stop watch, photographic equipment, etc.

IV. TEST PLAN

As described before, the model will be supported by the model carriage. It will be connected to the compressor, on the trailer carriage, with 2.5-inch pipe with flexible sections. The generator will be portable, but generally stationary, with only the flexible power cables attached to the compressor motor. The simulated deck traversing towing force (carriage towing cable tension) will be measured with compressor air off to obtain the tare force due to the model carriage and trailer carriage rolling friction plus any small restraint caused by the flexible power cables.

Obviously, the lowest cfm from the compressor, that will give an adequate airfilm between the model platform seal and the deck with 3 psi suction, must be determined. This will provide data for estimating the minimum power requirement that will be satisfactory for a full-scale installation. Therefore, less than rated compressor cfm to the model, with 3 psi suction, will be run for appropriate flows by adjustment of the air bleed-in valve located downstream from the flowmeter.

The static seal to deck clearance with cylinder air pressure zero will be set at 0.8 inch by the carriage screw adjustment and used for all tests unless a closer setting is required to obtain design suction with available cylinder stroke.

The deck size selected for the test is at least 21 feet long and 7 feet wide with a 12-inch margin all around to prevent the test rig from running off the deck. The deck test section is 6 feet long and the model will traverse this section; see Page 13. For tests with simulated deck obstacles, it is planned to locate the one-half scale hangar door sill or tie-down fitting, as the case may be, at the start of the six-foot test section of the deck so the entire model will traverse the obstacle.

Simulated deck traversing will be done by steadily rotating the winch hand crank. The time for the model to fully traverse the six-foot test section of deck will give the traversing speed; this will be no more than about 30 feet per minute (12-second traversing time). This is considered representative of full-scale maximum towing speeds. If the steady state varies, the traversing speed will be an average value which is also typical of an actual case. Two speeds will be tested, approximately 15 and 30 feet per minute.

The planned tests will be partially repetitive for the following deck conditions. No wet deck tests are planned to investigate the effect of water ingestion below the seal.

(a) Smooth deck

(b) Deck with standard Navy anti-skid coating. The roughness will be double size relative to this one-half scale model. If it is appropriate, some reduction of the roughness may be tried.

(c) One-half scale hangar door sill and track installed across start of the six-foot deck test section.   Also a track filler may be tried.

(d) One-half scale tie-down fitting installed on the deck centerline at start of six-foot deck test section.   It is assumed only one such fitting would be traversed at a time in the actual case.

(e) Same as (d) with tie-down fitting under seal at side of model (15.1-inch outboard centerline model).

The following table shows the planned test runs.   The test setup is shown schematically below.
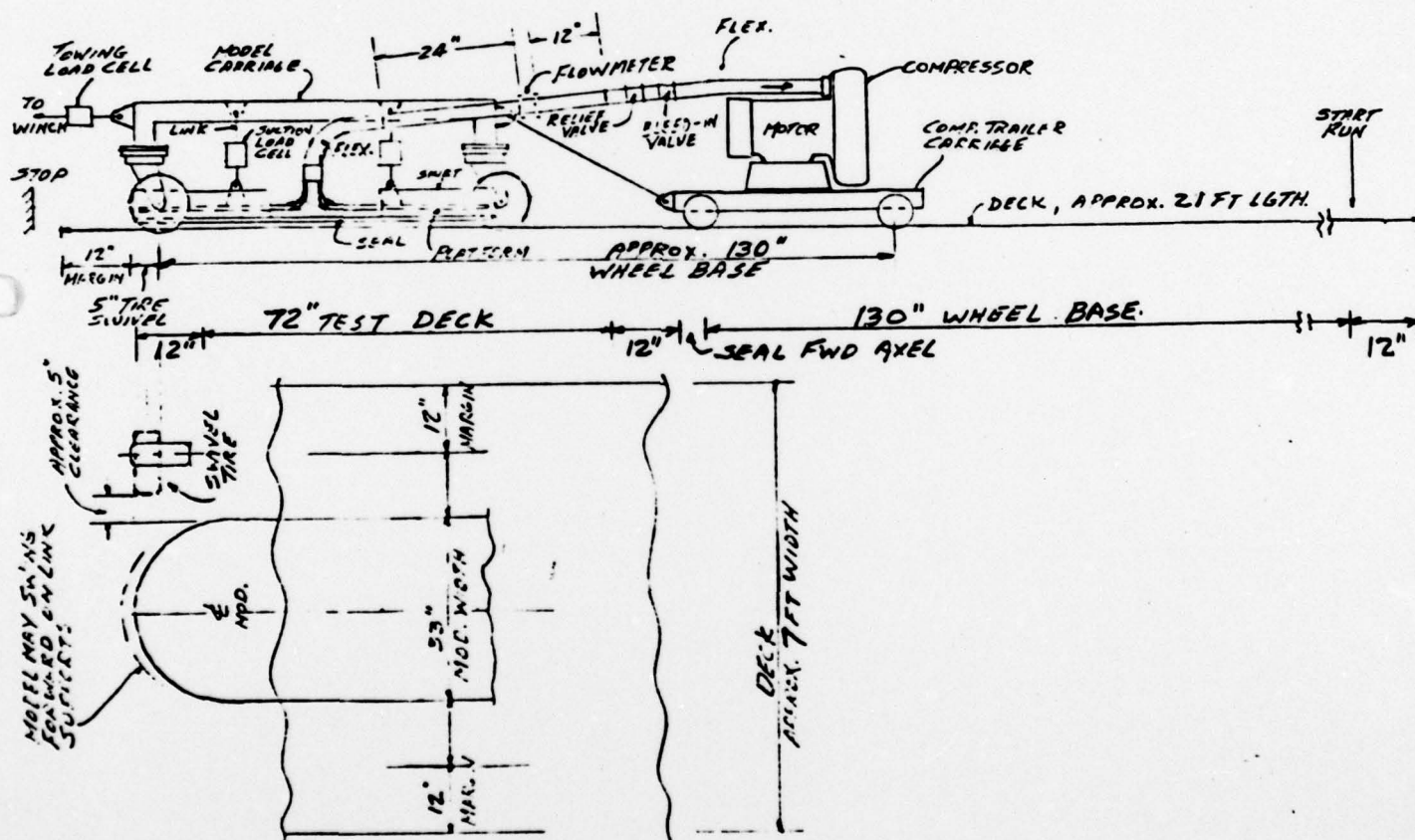
PLANNED TEST RUNS

Run No.	Deck Cond.	Air Bleed-in Valve Position	Air Flow MTR CFM	Cyl. Press. PSI (see Note 6)	Suction Above Plat-form PSI	Suction Below Plat-form PSI (Note 4)	Temp. Below Plat-form AMB. T °C	Static Wheel Axel to Deck (tire defl.) ins	Static Skirt to Deck (seal position) ins	Time to Traverse 6ft Deck Test sec.	Tow Cable Force (Note 5) LB	Condition Simulated
1	SMOOTH NO OBSTACLE	CLOSED	0	0	0	0		(5.2)(5.2)	(1.5)(1.5)	24	(24)	TARE HOLD-DOWN INOP-ERATIVE 15 FT/MIN TRAV. V
2	"	"	"	"	"	"		" "	" "	12	"	SAME BUT 30 FT/MIN
3-8	"	OPEN AS REQ'D	50 TO MAX BY 25 INCREMENTS	INITIATE SUCTION		3		" "	" "	STATIC	STATIC	EXPLORATORY BUILD-UP TO RATED CFM
9	"	CLOSED	MAX (175)	"	"	3				24	(24)	RATED CFM 15FT/MIN. TOW
10	"	"	"	"		3				12	"	SAME BUT 30 FT/MIN
11	"	OPEN AS REQ'D	AS REQ'D FOR MIN. TOW FORCE	"	"	3				24	(24)	MIN. REQ'D CFM 15FT/MIN. TOW
12	"	"	"	"		3				12	"	SAME BUT 30 FT/MIN
	REPEAT WITH VARIOUS DECK CONDITIONS (SEE P6 (12)) EXCEPT REDUCE EXPLORATORY CFM BUILD-UP (REF. RUNS 3-8) AS APPROPRIATE.											

NOTES - (1) SET AND/OR RECORD ALL ITEMS, (2) NOS. IN PAREN. ARE EST. APPROX. VALUES, (3) SKIRT TO DECK-MEASURE AT ENDS AND SIDES (4) ASSUME FOUR POINTS MANIFOLDED (5) RECORD BREAK-OUT FORCE AND ANY SIGNIFICANT VARIATION PARTICULARLY WITH DECK OBSTACLES, (6) RECORD VARIATION DURING TRAVERSING.
(7) VARY CYLINDER PRESS. (5 POINTS) WITH 3 PSI SUCTION (MAX. CFM) AND NO SUCTION. RECORD STATIC SKIRT TO DECK DIMENSION (CARRIAGE SUPPORTED TO ELIMINATE TIRE DEFL.)

V. APPLICATION OF MODEL DATA
TO FULL-SCALE AIRCRAFT

It should be recognized that these planned tests are in effect exploratory to determine if the system will work as expected. If it does, undoubtedly additional, more detailed testing will be indicated.

The recommendations in the Conceptual Design Study of the Rigid Skirt Hold-Down System (Report No. SAE 77-005) refer to model tests as qualitative in nature. It is expected that some of the tests will be qualitative; however, the model force data should be directly applicable to full scale.

It is suggested that full-scale calculations use the hold-down force per square foot of hold-down area (C_F), obtained from the model tests directly. For traversing, the model tow force will be reduced by the tare force with suction off and the seal above the deck. The remaining force will be the friction force due to the seal ($\Delta\mu_s$ in coefficient form). For full scale, the tow force will be

$$[(\text{Aircraft weight}) + (C_F A)] \times [\text{Aircraft rolling } \mu] + (C_F A) \times (\Delta\mu_s)$$

where A = suction hold-down area in square feet

An exception may be the case where deck obstacles such as open track channels are encountered where suction may be partially or entirely lost; these tests will be largely qualitative.

The model breakout force will be obtained and will be used to calculate the aircraft sliding tendency from a fixed position under adverse deck conditions of wind, deck slope, etc.